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## LETTUCE GROWING IN GREENHOUSES

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**C**RISP, TENDER LETTUCE, such as may readily be produced in greenhouses and placed in the hands of the consumer within a few hours from the time it is harvested, is increasing in popularity.

The crop may be grown in simple, inexpensive greenhouses, but correspondingly better results can be had when a large modern greenhouse is used.

Success in the growing of greenhouse lettuce depends on the use of a soil well supplied with organic matter and available plant food, the control of diseases and insect enemies of the crop, the use of varieties and strains adapted to the needs of the grower and the market to be supplied, and the closest attention to every detail of the management of the crop.

Satisfactory financial returns can be secured only when a well-grown, high-quality crop is packed in an attractive manner in containers of suitable size and placed in the hands of consumers in the shortest practicable time.

# LETTUCE GROWING IN GREENHOUSES

By JAMES H. BEATTIE, *senior horticulturist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

## CONTENTS

	Page		Page
Survey of the industry.....	1	Securing lettuce plants.....	11
Greenhouses suited to lettuce growing.....	3	Establishing the crop in the greenhouse.....	13
Relation to other forcing crops.....	4	Care of the crop.....	15
Intercropping.....	5	Harvesting and packing.....	17
Soil and its preparation.....	5	Storage.....	18
Manure, fertilizers, and lime for greenhouse lettuce.....	6	Yields of greenhouse lettuce.....	18
Varieties and seed.....	8	Diseases affecting greenhouse lettuce.....	20
		Insects injurious to greenhouse lettuce.....	22

## SURVEY OF THE INDUSTRY

THE wonderfully refreshing qualities of lettuce have made it by far the most widely used of the salad crops. Crisp, tender lettuce, such as is produced in modern greenhouses, can be delivered to the markets within a few hours after the product is harvested. Greenhouse lettuce is the oldest vegetable forcing crop grown in the United States, as large quantities of lettuce were produced in hotbeds and coldframes before the greenhouse began to attract attention for the culture of this crop. The production of lettuce in hotbeds is limited by the seasons, for it is seldom practicable to open a hotbed during cold weather without danger of injuring the crops. Some growers utilized modified hotbeds heated with a flue or with hot-water heat and so arranged that it was possible to enter them by using depressed walks.

Simple greenhouses built with the walks excavated below the surface and the roof made of two rows of hotbed sash with a ridgepole in the middle soon came into use for the forcing of lettuce, and these quickly demonstrated the practicability of producing greenhouse lettuce as an all-winter crop. Greenhouses of the type employed for the production of floricultural crops early came into use for the forcing of lettuce and shortly afterwards for the forcing of cucumbers, tomatoes, and other crops. Growers found that the economical production of vegetable forcing crops demanded a special type of structure, and the development of the modern vegetable-forcing house has been the result.

Boston, Mass., was the center of the first important greenhouse-lettuce industry; as early as 1880 at least one grower in that section was producing lettuce in glass houses. This was soon followed by a similar development at Grand Rapids, Mich., and the success of these

early growers led to the establishment of the industry in northern Ohio, Rochester, N. Y., Philadelphia, Pa., and many other points.

At present the greenhouse-lettuce industry centers around Boston, Mass.; Cleveland, Ashtabula, and Toledo, Ohio; Grand Rapids, Mich.; and Rochester, N. Y.

The demand for greenhouse-grown lettuce has gradually declined with the expansion of the field-grown lettuce industry. Modern transportation, refrigeration, and storage facilities have made it possible to supply the large-city markets with field-grown head lettuce every day of the year. In spite of the increasing demand for the field-grown head lettuce, there is still a market for the greenhouse product during the winter months.

Most of the lettuce grown under glass is of the loose-leaf or bunching type. Grand Rapids is the most widely grown variety. There are several strains of this variety.

The heading sorts are far more difficult to produce satisfactorily than are the loose-leaf varieties, and this has led many growers to devote their attention to the production of Grand Rapids or other loose-leaf kinds. While the difficulties often experienced in securing good yields of high-quality greenhouse-grown head lettuce deter many growers from attempting the production of these sorts, the uniform success of producers in the Boston, Mass., district and other sections where the forcing of head lettuce is an important industry shows that it can be done, provided adapted varieties are grown at the right season of the year and handled in the proper manner. Extreme care in preparing the soil, in controlling temperature, in ventilating, and in watering is necessary. Careless application of water, especially after the heads have begun to form, is liable to induce drop and other troubles. Many successful growers do not wet the plants at all during the heading period, depending on subirrigation or on the supply of moisture already in the soil for the maturing of the crop. Inexperienced persons should master the production of loose-leaf lettuce before attempting the growth of the more difficult heading kinds, for while the general cultural requirements of head lettuce are not materially different from those for loose-leaf varieties, it is a task for the most skillful greenhouse operators.

Profitable returns have not always been secured from the production of greenhouse lettuce, especially loose-leaf lettuce. The crop thrives at a low temperature, and great quantities are produced in frames and even outdoors in the milder sections of the country, much of this coming into competition with the greenhouse product. Unless transportation charges are such that a differential is established in favor of the greenhouse product, its production may become unprofitable. Having control of most of the factors influencing the development of the crop, the producer of greenhouse lettuce is able to handicap the long-distance shipment crop by growing a high-grade product, and, moreover, he can place it on the market in a perfectly fresh condition. Constant improvements are being made in structures for the production of the vegetables included in glass-farming enterprises, making it possible to secure crops with a minimum of fuel and labor. These and other factors help greenhouse crops to compete more successfully with outdoor crops.

## GREENHOUSES SUITED TO LETTUCE GROWING

Lettuce is not particular as to the type of forcing structure in which it is grown, and it is produced in many kinds of greenhouses, but cucumbers and tomatoes, being very particular as to their growing conditions, require greenhouses of a special type. Owing to the fact that the vegetable-forcing industry usually includes the production of several crops, it is necessary to use structures suited to the requirements of all the crops grown. Lettuce, cucumbers, and tomatoes are the crops to which the most attention is devoted, and they comprise a very large portion of the annual value of the vegetable-forcing crops grown in the United States. The greenhouse must be made to suit these crops, and as they must have a rather high and very uniform temperature and freedom from draft, excellent heating equipment is required. Although such houses are not absolutely essential to the successful production of the more hardy types of lettuce, it is unquestionably true that the crop thrives better in good greenhouses than in very simple structures. Those proposing to grow lettuce as their main crop will find it advantageous to build a good type of greenhouse.

The growing of greenhouse lettuce has developed to a point where growers often look upon it in terms of acres of land enclosed. The modern vegetable-forcing house is a structure designed to enclose the desired area of ground with a roof and side walls, making it possible to maintain temperatures and other conditions suitable for the successful production of the various crops. Houses of the ridge-and-furrow type (fig. 1) make it possible to include an almost un-

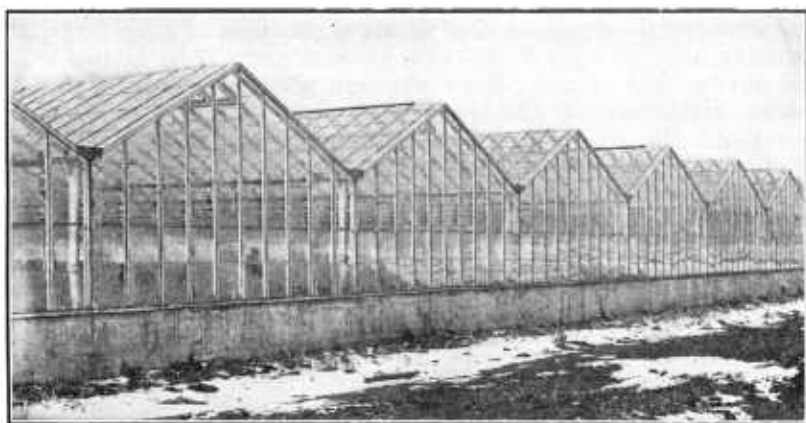


FIGURE 1.—Ridge-and-furrow greenhouses, extensively employed for the forcing of lettuce and other crops.

limited area of ground in what is practically one large house. Such houses are employed by some of the most successful producers of greenhouse lettuce. Large steel-frame houses (fig. 2) are extensively employed for the production of lettuce and other forcing crops and are almost ideal for their production. In the Boston area, where the production of lettuce in greenhouses has reached the greatest perfection, the so-called uneven-span house is the type almost universally em-

ployed. These structures as a rule are from 32 to 36 feet wide and from 200 to 600 feet long, with the ridge to one side; hence the name uneven span. They are so located that the long side of the roof has a southerly exposure. Other types are largely used for the growing of greenhouse lettuce, but in practically all houses the crop is grown on ground beds, as raised benches add to the expense and are not desirable for lettuce growing.

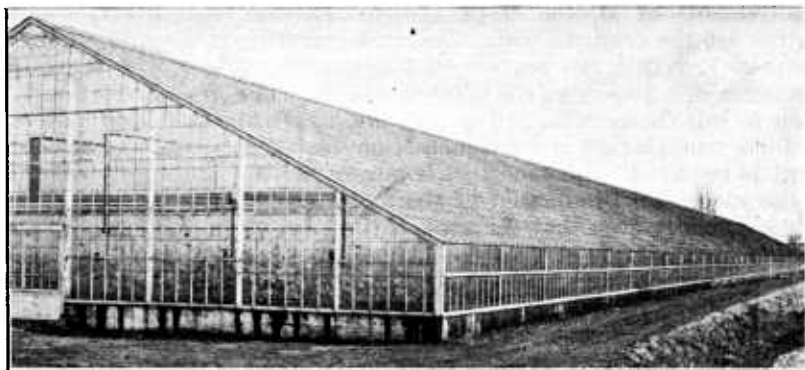


FIGURE 2.—Steel-frame greenhouses, from 40 to 100 feet wide and any desired length, largely used for the production of lettuce and other forcing crops.

#### RELATION TO OTHER FORCING CROPS

Of the three important vegetable-forcing crops, lettuce alone does well as a midwinter crop. Neither cucumbers nor tomatoes will make a satisfactory development during the short days of midwinter, and for this reason nearly all vegetable growers plant their houses to lettuce during this period. Some growers produce a crop of fall tomatoes, which occupy the space until about the first of January; then plant the space to lettuce, producing one crop; then plant cucumbers; or, producing from two to three crops of lettuce, occupy the house until summer. In other cases lettuce is planted early in the autumn, and successive crops are produced until time to plant cucumbers in the spring. The planting plans shown in table 1 are followed quite closely by many large growers.

TABLE 1.—*Greenhouse crop rotations*

Plan and crop	Seed sown	Plants set	Crop harvested
Plan 1: <sup>1</sup>			
Tomatoes.....	July 1-15	Aug. 15-30	Dec. 15-31
Lettuce.....	Nov. 15-30	Dec. 15-31	Mar. 15-31
Cucumbers.....	Feb. 1-15	Apr. 1-15	July 1-31
Plan 2: <sup>2</sup>			
Tomatoes.....	July 1-15	Aug. 15-31	Dec. 15-31
Lettuce.....	Nov. 15-30	Dec. 15-31	Mar. 15-31
Do.....	Feb. 1-28	Mar. 15-31	June 1-15
Plan 3:			
Lettuce.....	Aug. 1-15	Sept. 1-15	Nov. 15-30
Do.....	Oct. 15-30	Nov. 15-30	Feb. 1-28
Tomatoes.....	Jan. 1-15	Mar. 1-15	Before Aug. 1.

<sup>1</sup> The time between the removal of the cucumbers and the planting of tomatoes is used for soil sterilization.

<sup>2</sup> In part of the space it is possible to grow a third crop of lettuce. Growers who follow this cropping plan usually count on 2½ crops of lettuce.

These plans may be modified to suit conditions. In many large ranges it requires 2 weeks for the entire planting; consequently no exact dates can be observed. In fact, it is desirable to plant lettuce over an extended period, as it is then possible to plant and harvest continuously. As soon as the crop is removed, the soil is prepared for another crop.



FIGURE 3.—Lettuce grown as an intercrop between rows of cucumbers in a greenhouse. The lettuce is removed before the cucumbers reach the bearing stage.

#### INTERCROPPING

Owing to the fact that a fair crop of loose-leaf lettuce can be grown in about 6 weeks from the time the plants are set in the houses, it is sometimes used as an intercrop between such greenhouse crops as cucumbers. Figure 3 shows a range where this plan is being followed. Although the lettuce grown in this manner is of a rather poor quality, because the temperature is usually carried at the point best suited to the other crop and it does not have sufficient time to make a heavy yield, this practice frequently makes it possible to secure an appreciable additional return. Lettuce of the Grand Rapids type is sometimes grown as an intercrop with tomatoes, but here, too, the temperature best suited to tomatoes is too high for lettuce, and it must be removed before it has time to make a good growth. When planted as the main crop, it soon fully occupies the ground, leaving no space for companion crops. Head lettuce is more particular in its cultural requirements and is not well adapted to being grown as an intercrop with tomatoes, cucumbers, and other forcing crops demanding higher temperatures.

#### SOIL AND ITS PREPARATION

A naturally deep, well-drained, friable soil is considered best for the growing of greenhouse lettuce. The plant has a large root system, and it is particularly desirable that the soil be deep. Soils characterized as loams, containing a considerable portion of sand,



are well adapted to the crop. While many growers of the loose-leaf type of lettuce use soils of a rather heavy character, producers of head lettuce consider some sand an essential part of the soil used. As several different vegetable crops are produced in most ranges, the soil must be suitable for all. The important forcing crops do best on soils having a fairly light texture, and it is not difficult to select one well adapted to all the crops to be grown. It should be remembered that frequent applications of stable manure and other forms of humus essential to the successful production of greenhouse vegetable crops tend to lighten the soil, and the original selection should be made with this factor in mind. To produce lettuce of good quality a congenial environment is essential, including a soil of excellent physical condition and well supplied with readily available plant food, so that a rapid and uninterrupted growth can be made. It is undoubtedly true that the methods followed in handling the soil are of more importance than its original character.

A thoroughly fined seedbed is requisite for the production of a successful crop of lettuce. The plants are small and delicate when set in the houses, and unless the ground is free from lumps it is impossible to set them in such a manner that they will make a quick recovery from transplanting and have a free and unrestricted root development. Because the root system of a lettuce plant is more extensive than is generally supposed, it is desirable that the preparation of the ground extend to a depth of 7 to 10 inches, thus giving room for root development and promoting the aeration and drainage so essential to the securing of a good crop.

When the work of preparing the seedbed is done by hand, such tools as a spading fork, spade, and rake are used, particularly in small houses with ground beds or larger houses fitted with raised benches. Where cheap labor can be secured, the hand preparation of the soil is a good practice. In many cases the crop is harvested in the morning and a new one planted in the afternoon. Plowing and harrowing the ground in the houses with the aid of horse- or tractor-drawn tools have much to recommend them, especially where large areas are to be handled. Small gasoline tractors equipped with rotating tools are coming into common use for preparing soil in large greenhouses. Whatever the method followed in preparing the seedbed, it should be thorough in every particular.

#### MANURE, FERTILIZERS, AND LIME FOR GREENHOUSE LETTUCE

##### MANURE

Manure has always been the main dependence of the grower of greenhouse lettuce. Formerly abundant supplies made it unnecessary to resort to the use of other forms of organic matter and plant food. Many growers now find it difficult to secure supplies of manure sufficient to maintain the fertility of the soil in their houses at reasonable cost and are becoming more and more dependent upon other sources of organic matter and plant food. A certain amount of manure is desirable in the production of all vegetable-forcing crops. In cases where growers find it impossible to obtain supplies from their former sources, they have resorted to the use of manure from stock farms or from dairies, maintained largely for the purpose of assuring

them a satisfactory supply. Where it is possible to secure as much manure as can be used to advantage, it is customary at the beginning of the crop season to apply about a ton to each thousand square feet of space, supplementing it by later applications made between crops. In the large vegetable houses without raised benches the manure is usually distributed by a team attached to a dump wagon or a manure spreader.

#### COMMERCIAL FERTILIZER

Large yields of high-grade lettuce can be obtained only when the crop is supplied with an abundance of readily available plant food. Complete fertilizers containing the three elements, nitrogen, phosphorus, and potassium, generally give greater increases in yield than applications of a single element. Phosphorus is commonly the critical element in lettuce fertilization. In general, a fertilizer for lettuce should carry a high percentage of phosphorus. Many growers use a good commercial fertilizer containing 3 to 5 percent of nitrogen, 8 to 12 percent of phosphorus, and 4 to 8 percent of potassium at the rate of 1,000 to 2,000 pounds per acre at the time the soil is prepared.

Side dressings of nitrate of soda or sulfate of ammonia are sometimes made. Chemical fertilizers can be used only in moderate quantity, as injury may result from heavy applications, especially when highly soluble materials like nitrate of soda are used. Some growers prefer to apply the nitrogen in the form of dried blood, tankage, fish scrap, or some other organic form, since these materials can be used with less danger of injury. Nitrate of soda and sulfate of ammonia used as side dressings should not exceed 200 pounds per acre for each crop.

Experimental evidence indicates that phosphorus in the form of superphosphate is more effective in increasing yields than phosphorus in the form of bonemeal or rock phosphate.

Potash may be applied in the form of muriate or sulfate of potassium. Small amounts of potash are carried in kainit, manure salts, and hardwood ashes, but these are not widely used as sources of potash.

Phosphorus and potash should be applied in the form of a complete fertilizer and thoroughly incorporated with the soil before the crop is planted. These are both slow-acting elements, and little is to be derived from their use in side dressings after the crop is started.

#### LIME

Lettuce is sensitive to the acid conditions of most soils, although on certain soils it apparently tolerates an appreciable degree of acidity. Applications of lime should never be made without first determining accurately the lime requirement of the soil. The county agricultural agent or the State experiment station will make this determination for the grower without charge. In liming acid mineral soils it is usually safe to apply approximately the quantity indicated by the lime-requirement test, but that quantity should not be exceeded. Excessive liming gives very unfavorable results. Experiments have shown that very heavy applications of lime upon certain very acid muck or organic soils are not advisable, even though the requirement of heavy applications may be indicated by a test. Such soils must be

limed with great care and then only after preliminary trials on a small area have shown what quantity is best to use.

Ground limestone, ground burned lime, or ground hydrated lime may be used. Approximately one-half as much burned lime or three-fourths as much hydrated lime is as effective as a given quantity of ground limestone.

#### VARIETIES AND SEED

Of the three classes of lettuce, loose-leaf or bunching, cabbage-heading, and Cos or Romaine, the loose-leaf is the most generally grown in greenhouses. The production of the heading type has been commercially profitable only in the Boston area. The production of Cos lettuce under glass has been tried at various times but without much financial success. Figure 4 shows specimen plants representative of the two leading varieties grown under glass: *A*, Grand Rapids, the most widely grown loose-leaf variety; *B*, Bel-May, a heading variety grown extensively in the Boston section.

#### VARIETIES

A very large portion of the lettuce grown under glass in this country is of the variety Grand Rapids. The original strain is reported to have been developed by a grower near Grand Rapids, Mich., by years of selection from Black Seeded Simpson. There are now several distinct strains of Grand Rapids, each popular with growers in different producing areas.

The Washington strain of this variety was developed by the United States Department of Agriculture at the Arlington Experiment Farm, Arlington, Va. This strain has rather coarse leaves that are much savoyed. It is very popular in the Grand Rapids, Mich., section, where 90 percent or more of the crop is of this strain.

A strain of Grand Rapids that is adapted for forcing and resistant to tipburn has been developed by the Ohio Agricultural Experiment Station at Wooster, Ohio. This strain is a darker green than the original. The Ohio strain is grown quite extensively in the area around Cleveland, Ohio.

Several varieties of head lettuce have been grown under glass with varied success. However, because of the more exacting requirements of the heading sorts many greenhouse-lettuce growers have returned to the more reliable loose-leaf variety, Grand Rapids.

Only in the Boston area has the growing of head lettuce under glass proved profitable. The Massachusetts Agricultural Experiment Station at Waltham has developed a head lettuce adapted for forcing that is resistant to downy mildew. This variety was introduced in 1928 under the name Bel-May. It now constitutes practically the entire crop grown under glass in the section around Boston. It is a butter-head type of lettuce, having dark-green tender leaves tinged with red pigment. The Bel-May resulted from selection in material obtained from a cross of May King with the old, reliable forcing lettuce, Hittinger Belmont. The growing of this variety is confined largely to the Boston area.

The heading varieties, May King, Hittinger Belmont, Big Boston, and Salamander, have at various times been grown under glass.

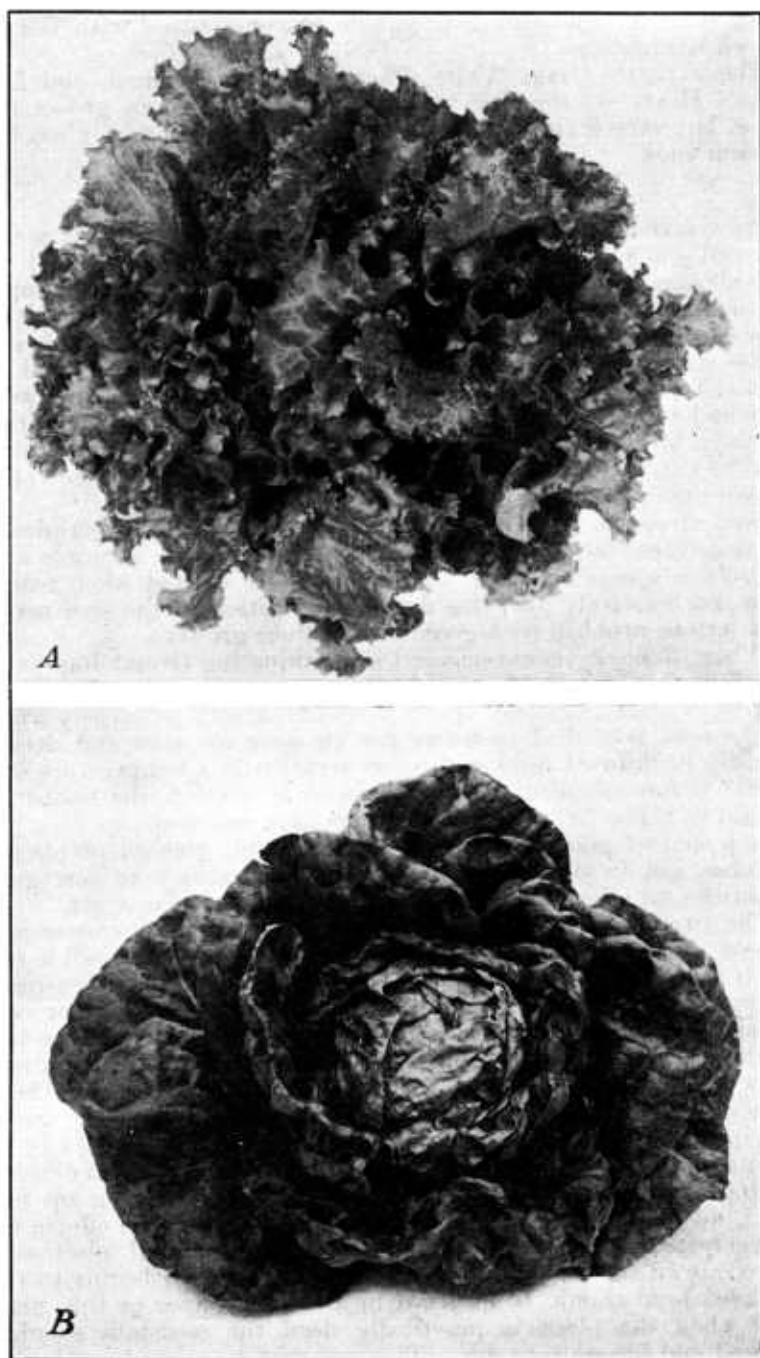


FIGURE 4.—Heads of the two most important varieties of lettuce grown under glass: *A*, Grand Rapids; *B*, Bel-May. (Courtesy of the Massachusetts Agricultural Experiment Station.)

None of these has proved profitable in competition with the field-grown head lettuce.

The varieties Giant White, Paris White or Trianon, and Dwarf White Heart, of the Cos type of lettuce, have been grown under glass, but very little lettuce of this type is grown under glass at the present time.

#### SEED

Irrespective of the variety grown, the seed should be of a strain especially adapted to forcing work and to the conditions found in the greenhouses where the crop is to be produced. Commercial supplies of such seed are limited, and many growers have found it advantageous to grow their own supply, as it does not require much greenhouse space to produce sufficient lettuce seed to plant a considerable area. From 60 to 100 plants of Grand Rapids lettuce will produce a pound of seed. The number of seed per pound varies with the variety, largely because of the difference in size of seed. The seed of Grand Rapids is small compared with that of other varieties grown under glass.

Seed of the variety Grand Rapids is often difficult to germinate at temperatures above 70° F. However, as greenhouse lettuce is almost entirely a winter crop and the seedlings are started when temperatures are relatively low, this dormant condition of the seed may not be a serious problem with greenhouse lettuce growers.

Where difficulty is experienced in germinating Grand Rapids seed, an effort should be made to hold the temperature below 70° F. for a few days after planting. Poor germination can be largely avoided if the seed is soaked in water for an hour or more and dried off slightly in diffused light with good aeration at a temperature of 60° to 65° before planting. After the seed is planted, the temperature should be below 70° until the seedlings have emerged.

A pound of good lettuce seed should supply enough plants to set an acre, but in practice, growers find it necessary to sow greater quantities, to allow for poor germination, loss of plants, etc.

The production of lettuce seed by the greenhouse owner in the houses where the main crop is to be grown makes it possible to develop a strain suited to his needs and, by continuing this strain, to assure himself that his crop will always be uniform. The procedure usually followed is to select a few plants of the desired type in the main crop and transfer them to pots when the main portion of the crop is harvested, so they can be carried to the seed stage. The best time of the year to do this is during the late spring, so the seed can be ripened during the early summer. The selections should be ideal plants of the type and variety being grown. If it appears desirable during the seeding stages to discard any not measuring up to the ideal, no further attention should be paid to these, the efforts being concentrated on the more promising ones and the final selection narrowed down to only a few plants. When the seed begins to ripen, the seed head should be enclosed in a sack of paper or thin muslin, and when the plant is practically dead the seedstalk should be severed and hung up to dry. The seed may be rubbed out by hand, each lot being preserved and planted separately. If well-developed plants have been saved there should be enough seed from each to

plant a good-sized area. This planting should be in the commercial number of off-type plants is sufficient cause for the remainder of the crop used for commercial purposes. With the crop from each of the selected plants growing side by side, it is an easy matter to determine which comes nearest to the desired type. Any considerable number of off-type plants is sufficient cause for the rejection of the lot in which they occur. The best lot should be used as the supply of stock plants for growing the seed supply for the entire range, and all plants not wanted for seed purposes should be removed and disposed of in the usual manner. It is a good plan to leave the plants selected for seed in the place where they were grown until the crop is harvested; the number selected and lifted for seedling will be determined by the quantity of stock seed that it is desirable to produce. The stock-seed supply should be replenished every 2 or 3 years by a repetition of the methods used for its establishment. It is seldom advisable to attempt to select and move sufficient plants from the main crop for the production of the entire seed crop. A better practice is to establish the stock seed in this manner, using this to plant the seed crop in a separate house, because lettuce grown for seed purposes should have more room than is required for the commercial crop. With most varieties sufficient room will be given the seed plants if they are spaced 12 to 15 inches apart. Figure 5 shows a crop of greenhouse-grown Grand Rapids lettuce seed for forcing.



FIGURE 5.—A seed crop of Grand Rapids lettuce grown in a greenhouse.

#### SECURING LETTUCE PLANTS

Greenhouse lettuce is usually grown from plants that are started in a separate place and when of sufficient size are transferred to the houses where the crop is to be matured. This practice economizes greenhouse space, as it is unnecessary to occupy this space with the crop during its early stages, when it can be cared for in a better manner in a separate enclosure, making it possible to secure a uniform stand in the growing house.

## SOIL FOR LETTUCE PLANTS

Owing to the small size of lettuce seed and the delicate nature of the young plants, it is essential that the soil used for growing the plants be of a moderately loose and friable quality, free from lumps, and thoroughly screened so as to remove any clods, sticks, or stones. As little food is stored in the seed, the plant immediately throws out roots in search of nourishment, and if these come in contact with lumps or foreign matter the plant is liable to be dwarfed. A good soil for the production of lettuce may be prepared by composting 2 parts of sod and 1 part of well-rotted horse or cattle manure.

If the soil used for making the compost does not contain a considerable proportion of sand, it is a good plan to add some sand to this material. The compost pile should be prepared several months before the soil is needed, cut down, and turned once or twice before it is used for growing the plants. If the manure used for the compost is not of the best quality, it is well to add a few pounds of good mixed fertilizer to each ton of the compost. Many growers make a practice of using either raw rock phosphate, superphosphate, or bone-meal, mixing it with the compost when the pile is turned for the first time; from 2 to 4 pounds of any of these to each ton of compost is usually sufficient. Other growers use manure to which applications of raw rock phosphate have been made in the stable. The main point to keep in mind is that lettuce plants require plenty of plant food and that it is better to apply this to the soil before the plants are started, so that they can make a rapid growth unhampered by lack of food. The screening can well be done at the time the soil is turned for the last time. Soil prepared according to these suggestions as a rule will give good results in the starting and growing of lettuce plants. Soil prepared from materials that have not been used for growing lettuce or related crops should be safe from all such lettuce diseases, except nematodes, as are carried in the soil, but the best growers prefer to sterilize all soil used for the production of the plants. The sterilization is particularly necessary when the soil is liable to be infested by nematodes or damping-off fungi. The methods followed in accomplishing this are fully described in another bulletin.<sup>1</sup>

## TIME WHEN SEED SHOULD BE SOWN

Plants for early-fall and late-spring crops will grow in a shorter period than is required for those for midwinter crops. From 3 to 6 weeks is necessary for the production of plants from seed, depending on the season of the year and the size of the plants desired. After from 7 to 12 days in the seedbed, the plants are placed in pots, flats, or the benches of the nursery house, where they are carried to the size needed for greenhouse use.

## SOWING THE SEED

Lettuce seed may be sown broadcast or in drills. Flats, ground beds, or raised benches may be used for starting the seedlings. Sowing in drills is preferable, and seedlings started in regular greenhouse flats 12 inches wide, 24 inches long, and 3 inches deep, inside

<sup>1</sup> See Farmers' Bulletin 1320, the Production of Cucumbers in Greenhouses.

measurements, can be easily handled and cared for. The shallow furrows, spaced about 2 inches apart, are usually made with the edge of a lath, and the seed is placed in these drills with the aid of the flap of a seed packet. About 8 to 12 seeds to the inch is the rate of seeding usually followed. Leafmold, muck, or a very light-textured soil is used to cover the seed to a depth of not more than an eighth of an inch. The flats are then covered with burlap, sprinkled, and placed where they can be partly shaded, to prevent their drying out too rapidly. The burlap is removed when the plants begin to come up. A temperature of 60° to 70° F. is satisfactory until the plants come through the ground, after which it should be reduced to prevent a too-rapid, spindling growth. Care must be taken not to overwater the seedlings, as too much water induces damping-off and may also cause weak, spindling plants.

#### TRANSPLANTING

Transplanted plants are usually stronger and more uniform, but the practice increases the cost of the crop. Many growers of loose-leaf lettuce do not transplant seedlings grown for the fall crop, while some do not transplant for later plantings. Transplanting is usually profitable for loose-leaf lettuce, especially for seedlings for the mid-winter and early-spring crops. Heading sorts are more particular in their requirements, and the plants are almost universally transplanted, some of the best growers transplanting them twice.

Transplanting takes place in a week to 12 days after seeding and is an operation requiring considerable care, as the young plants must be handled so as to avoid breaking and bruising. The soil must be uniformly firmed around the roots, or uneven growth will result. In some cases the seedlings are transplanted to paper bands or to pots, but the more common method is to shift them to the standard greenhouse flats, setting them about 2 inches apart each way, with from 70 to 100 plants in each flat.

After the plants have been transplanted they should be watered with a fine sprinkler and placed in a shaded house until they become established, a special greenhouse usually being set aside for plant growing. Figure 6 shows such a house occupied by lettuce plants. Great care is given to watering the plants.

In large establishments, where planting and harvesting are going on continuously, it is necessary to make successive sowings of seed, so that a constant supply of plants will be assured. In many of these ranges the helpers used for this part of the work are kept constantly employed in transplanting, and as many as 5,000 plants each are transplanted in a day by those accustomed to the work.

#### ESTABLISHING THE CROP IN THE GREENHOUSE

##### PLANTING DISTANCES

Grand Rapids lettuce is usually set from 7 by 7 to 9 by 9 inches apart, but some growers set it 6 by 9, others 7 by 9 inches; it is probable, however, that more growers set it 8 by 8 inches than at any other distance. The heading varieties, Bel-May, May King, and Salamander, are set from 7 by 7 to 8 by 8 inches apart, as most growers believe it is best to crowd them a little in order that a great num-



ber of moderate-sized heads may be produced. The number of plants required to set each 1,000 square feet and each acre of bed surface at varying distances is given in table 2.

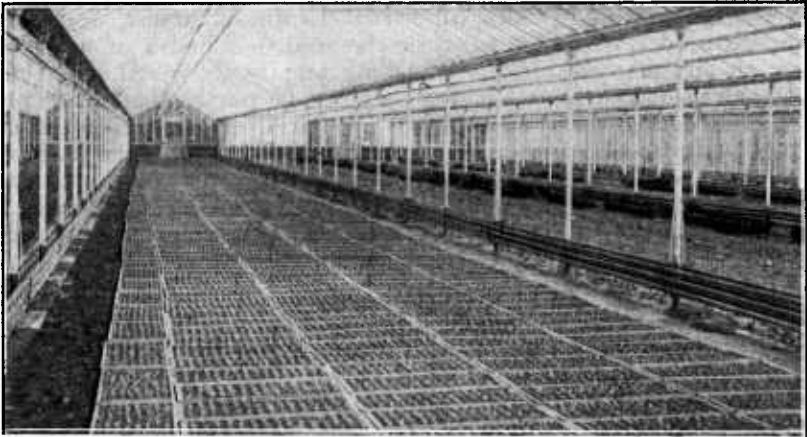


FIGURE 6.—A lettuce plant house. Plants for a 10-acre range are produced in this house.

TABLE 2.—Number of lettuce plants required per 1,000 square feet and per acre

Distance apart	Plants for—		Distance apart	Plants for—	
	1,000 square feet	Acre		1,000 square feet	Acre
6 by 7 inches.....	3, 429	149, 368	7 by 8 inches.....	2, 571	111, 993
6 by 8 inches.....	3, 000	130, 680	7 by 9 inches.....	2, 286	99, 579
6 by 9 inches.....	2, 667	116, 175	8 by 8 inches.....	2, 250	98, 010
7 by 7 inches.....	2, 939	128, 023	8 by 9 inches.....	2, 000	87, 120

#### SETTING THE PLANTS IN THE HOUSES

The work of setting the plants is greatly expedited by using a device for making holes that consists of a wide board corresponding to the size and the shape of the beds and having wooden pegs about an inch and a half in diameter and 2 inches long inserted in rows at the proper distance for the plants. Figure 7 shows a marker of this description in use in a large range of ridge-and-furrow houses, where the board is of such length that it just reaches across the 12-foot beds. The board is set in the proper position for the first row of holes and pressed down, then removed to the correct position for the next rows and left there to serve as a working board for the planters while the plants are set in the holes already made, when it is again moved, exposing another set of holes. The process is repeated until the entire area is covered. With large areas it may be necessary to plant in strips, as it would be impracticable to handle a marker more than 14 to 16 feet long. Other marking devices are used, but the type described is probably as satisfactory as any.

When grown in flats the plants may be easily transferred to the houses and distributed at suitable intervals. A knife run between the rows of plants separates them so that they can be lifted from the trays and set in position in the holes already made by the marker. Care should be exercised to firm the soil uniformly about each plant, and when in the ground they should be given a thorough wetting, using a fine spray to avoid injuring the young lettuce.



FIGURE 7.—Setting lettuce plants in a greenhouse. The board shown serves as a marker and also as a support for the women doing the work.

### CARE OF THE CROP

#### TEMPERATURE AND VENTILATION

Lettuce is a cool crop, being ordinarily grown at temperatures of 45° to 50° F. through the night and some 10 degrees higher during the day. Its ability to thrive at such temperatures adds to its popularity as a midwinter crop. It must not be concluded that it is permissible to aid in maintaining these low temperatures by keeping the houses closed, as ventilation is extremely important, especially with head lettuce. Lettuce not supplied with an abundance of fresh air is likely to be soft, of poor quality, and more liable to drop, mildew, and tipburn than plants in a better environment. The best growers take the greatest care to give the crop proper ventilation without sudden fluctuations in temperature.

#### CULTIVATION

Proper preparation of the soil before the plants are set is the most important part of the cultivation of greenhouse lettuce. With a soil thoroughly prepared to a depth of several inches it is usually unnecessary to do more than maintain a very shallow soil mulch, using such tools as a hoe, scuffle hoe, or weeder. There is great

danger that the roots may be disturbed through too-deep cultivation. In houses where the walks are only a few feet apart the center area can be cultivated by workmen standing on them and using ordinary garden tools. In other cases boards resting on low trestles are placed across the beds, so that the workmen can reach the middle of the beds from these. Cultivation ceases when the plants begin to cover the ground.

#### WATERING

Lettuce requires considerable quantities of water, but great care must be taken to apply it in a manner that will not induce such diseases as drop and mildew. The lettuce plant thrives best with a constant, uniform moisture supply. Rapid growth is desirable during the early stages; hence there is less danger from heavy watering during that period than when the plants are near maturity. Wide fluctuations in moisture supply should be avoided at any stage in the development of the plant. Tipburn and fungus diseases are likely to be much more destructive if the plants are very succulent. After the crop covers the ground, obstructing the free circulation of the air around the plants, the danger from overapplications of water becomes greater, but this should not deter growers from supplying the lettuce with sufficient moisture for its best development. The best growers make a practice of watering during the forenoon, for there seems to be a great deal of risk incident to the application of water later in the day, when the plants cannot dry off before nightfall.

The methods of applying water determine to a great extent the quality of the crop. Lettuce is a tender vegetable that cannot withstand heavy spray; consequently the watering must be carried on with exacting care, for applying it with a hose not fitted with a fine spray may ruin a good prospective crop.

Subirrigation, or the application of water through lines of drainage tile buried in the soil, is a method of watering greenhouse crops that is worthy of far more attention than it has received. Experimental work carried on at the Ohio Agricultural Experiment Station and by others has shown that subirrigation gives excellent results in growing greenhouse lettuce. By running the water into lines of tile it is possible to saturate the soil without wetting the foliage; moreover, some growers make a practice of applying dilute liquid manure or solutions of nitrate of soda through these same lines.

Overhead irrigation systems are very extensively employed in the growing of greenhouse lettuce. Lines of pipe with nozzles inserted every few inches are installed on the posts supporting the roof or gutters of the houses, the locations being determined by the width and type of the structure, one line of pipe to every 40 or 50 feet as a rule being sufficient if so located that a uniform distribution of the water is secured. In ridge-and-furrow type houses of moderate width a common plan is to place an irrigating line on the posts supporting the gutters, one line to every alternate house, and arrange them so that the pipe can be swung to water one side, then the other, movement being made possible by a swing joint near the end of the line. Such a system enables the operator to water his crop with the minimum of labor, insures a uniform distribution of the

water, and removes the danger of injury through violent dashing, as the water coming from the nozzles of the overhead system in the form of a fine spray usually takes the temperature of the air before striking the plants.

#### HARVESTING AND PACKING

From 9 to 14 weeks are required from the time the plants are set in the houses until the crop is ready to harvest, but the length of the period is determined by the season of the year and the size of the plants when they are harvested, a shorter time being required in fall and spring than in midwinter. No specific rule can be given to determine the best time for harvesting the crop. With the heading sorts the heads must be well formed with well-bleached centers, but the cutting of the crop must not be delayed until rotting begins, as the lettuce becomes bitter and tough through age. The grower usually wishes to secure a maximum growth, but if prices are particularly favorable a smaller yield may give a larger return. If tip-burn or other similar troubles appear it may be necessary to hasten the harvesting of the crop. If loose-leaf lettuce is cut when the plants have made their maximum development but before they begin to lose in quality, it will usually remain in marketable condition over a longer period than the heading sorts. Cos lettuce is ready for harvesting when the hearts are well filled with blanched leaves. Figure 4, *B*, shows a head of Cos in prime condition for market.

Butcher knives are usually employed for cutting the plants just above the surface of the soil. Some growers pack the lettuce in the houses as it is cut, while others merely remove the discolored lower leaves and place the lettuce in containers in which it is taken to the packing house. Figure 8 shows a harvesting scene in a range where the lettuce is roughly trimmed when cut, placed in bushel baskets, and transferred to the packing shed, where it is trimmed, washed, and



FIGURE 8.—Harvesting loose-leaf lettuce. The plants are cut just above the soil, roughly trimmed, and packed in baskets for transferring to the packing shed.

packed in paper-lined barrels. Figure 9 illustrates the methods used in handling the lettuce. Round stave baskets, splint baskets holding from 3 to 6 pounds of lettuce, and other containers are employed for shipping the crop. Figure 10 shows the tubs used for washing the lettuce as it is harvested and the sugar barrels, holding 90 pounds of lettuce, used as shipping packages in a range where the crop is packed as cut. When apple barrels are used, 60 pounds of lettuce is packed in each. When filled, the barrels are transferred to the shipping room, covered with burlap, and immersed in water for a few minutes, holes being bored in the bottoms to facilitate drainage.

Head lettuce is handled in much the same way as the loose-leaf sorts. Most growers cut the lettuce and transfer it to the packing house, where it is trimmed and packed without washing or is washed by taking a head in both hands with the outer leaves pressed around the head and immersed in water once or twice, after which it is placed in the shipping package with the root end up. Bushel baskets holding from 2 to 3 dozen heads, half-bushel or bushel hampers, crates holding from 2½ to 4 dozen, bushel boxes, or other containers are used. The marketing of greenhouse lettuce would be simplified by the adoption of standard containers.

Cos lettuce is handled in much the same way and in the same kind of packages as head lettuce.

Some water is necessary to keep lettuce from withering while in transit, and the quantity adhering to it when washed seems to be sufficient, but when barrels or other containers immersed in water after packing are used, care should be taken to provide proper drainage.

Lettuce freezes at about 31° F., and, when shipped in cold weather, it must be well protected, or serious losses may result. Lining the packages with paper affords considerable protection, but in hard freezing weather much care must be taken to prevent injury to the crop while in transit.

#### STORAGE

Artificial cold storage is sometimes employed for keeping lettuce for short periods, usually to avoid marketing during periods of low prices. Work carried on at the Arlington Experiment Farm shows that Big Boston head lettuce stored at a temperature of 34° F. may be kept in good condition for about 3 weeks.

#### YIELDS OF GREENHOUSE LETTUCE

The yield of greenhouse lettuce depends on the vigor of the crop and its stage of maturity when cut; if harvested early the yield may be materially reduced. Of loose-leaf lettuce a crop of from three-fourths of a pound to 1 pound per square foot of bed is usually obtained, but many growers secure much larger yields. The strains of Grand Rapids lettuce produced at the Arlington Experiment Farm have repeatedly yielded a pound and a half per square foot, individual plants weighing over a pound being common. Head lettuce gives about the same yields as the loose-leaf sorts, with plants weighing from ½ to 1 pound each. Yields of Cos lettuce are similar to those of other sorts.



FIGURE 9.—Washing and packing loose-leaf lettuce.



FIGURE 10.—Packing lettuce in a greenhouse near the location where it was grown.

A pound per square foot of bed means a yield of over 20 tons per acre, and although the price per pound may be rather low the return per acre is high. The conclusion should not be drawn that the production of greenhouse lettuce is always profitable, because it is expensive to maintain greenhouse acreage and the gross returns must be large. It is impossible to make a general statement in dollars and cents of the cost of growing greenhouse lettuce. Such factors as interest on the investment, depreciation on the houses, management, fuel, labor, supplies, and selling expenses are important, but with a properly located range and a high-grade crop greenhouse lettuce should prove profitable.

#### DISEASES AFFECTING GREENHOUSE LETTUCE<sup>2</sup>

##### DROP

Lettuce drop<sup>3</sup> is possibly the most serious disease affecting the crop in the greenhouse. It is characterized at first by a wilting of the outside leaves, usually rapidly followed by the wilting and collapse of the entire plant. Affected plants show a soft watery rot of the stems and leaves near the surface of the soil, which decayed parts are usually covered by conspicuous cottony white wefts of fungus or mold in which are developed black seedlike fungus bodies.

The disease is particularly liable to cause trouble during damp, cloudy weather. Too high temperature, improper ventilation, overwatering the crop, and crowding the plants in the beds tend to increase the ravages of the disease. Proper management of the crop, especially the sparing use of water during the 3 or 4 weeks preceding harvest, tends to hold the disease in check. It is advisable that diseased plants, including taproots and surrounding soil, be removed and destroyed as soon as evident, in order to check the spread of the disease to adjacent plants and prevent the formation of the seedlike fungus resting bodies mentioned above, which remain in the soil and produce the disease in succeeding crops. Where the drop causes heavy losses, a practicable and very effective remedy is the sterilization of the soil, preferably by steam,<sup>4</sup> although under some conditions hot water<sup>5</sup> or formaldehyde may be used to good advantage. The use of fresh soil serves the same purpose as soil sterilization if disease-free soil is obtained.

##### BOTTOM ROT

Bottom rot<sup>6</sup> is destructive in some sections, especially on heading varieties of lettuce, which grow with the outer leaves resting on the ground. The disease is characterized by a brown soft rot of the leaves, beginning where they rest on the ground and extending into the head. It is distinguished from drop by the absence of white wefts of mold and by the fact that the stem of the plant is not rotted. It is favored by moisture and can often be satisfactorily controlled by care in watering, especially by using no more water than is es-

<sup>2</sup> Prepared by the late Ivan C. Jagger, formerly senior pathologist, Division of Fruit and Vegetable Crops and Diseases.

<sup>3</sup> Caused by *Sclerotinia libertiana* Fekl. and *S. minor* Jagger.

<sup>4</sup> See Farmers' Bulletin 1320, the Production of Cucumbers in Greenhouses.

<sup>5</sup> See Farmers' Bulletin 1371, Diseases and Insects of Garden Vegetables.

<sup>6</sup> Caused by *Rhizoctonia* sp.

sential for the growth of the crop after the plants begin to shade the ground. When this treatment is not effective it is necessary to resort to soil sterilization, as for drop.

#### GRAY MOLD

Gray mold<sup>7</sup> attacks only plants that are already affected by other diseases or much weakened by unfavorable growing conditions. It causes a brown soft rot, and in advanced stages affected parts are covered with a grayish mold or fungus growth. It often follows tipburn, starting in the brown dead leaf margins. Trouble from gray mold need not be feared if the crop is so managed that strong, vigorous growth without tipburn is obtained.

#### MILDEW

Lettuce mildew<sup>8</sup> is characterized by yellowish or brownish spots in the outer leaves, covered on the lower and sometimes on the upper surface by a white fuzzy mildew. Insufficient ventilation, overwatering, and fluctuating temperatures are liable to induce trouble from this disease. Careful management of the houses and the crop as a rule is effective in controlling it.

#### ANTHRACNOSE

Anthracnose<sup>9</sup> is known also as shot hole or rust. It results in brown, roughly circular spots on the leaves, the brown tissues often falling out to produce shot holes or on the midribs sunken spots. The disease is favored by overwatering, especially where water is applied as a coarse spray which spatters soil on the plants, and by low temperatures. Remedial measures include the sparing use of water, the application of water as a fine mist or a slow stream from a hose or by subirrigation to prevent spattering soil on the leaves.

#### ROSETTE

Rosette causes considerable loss to lettuce growers. The disease is caused by a fungus<sup>10</sup> that lives on the roots, interfering with the nutrition of the plants and resulting in dwarfed, stunted heads. It is often induced by improper setting, faulty fertilization, or poor soil conditions.

#### TIPBURN

Head lettuce, and to a less extent leaf lettuce, is subject to tipburn, or a dying and browning of the margins of the leaves making up the central portion of the plant. The primary cause of the disease is too high temperature, although an excessive amount of nitrogenous fertilizers, especially when there is a deficiency of other fertilizer elements, makes crops more susceptible. Tipburn is usually the result of a few days of dark, cloudy weather, during which the houses are run at rather high temperatures with little or no ventilation and

<sup>7</sup> Caused by *Botrytis vulgaris* Fr.

<sup>8</sup> Caused by *Bremia lactucae* Reg.

<sup>9</sup> Caused by *Marssonina panattoniana* Magnus.

<sup>10</sup> *Rhizoctonia* sp.



the growth is rapid and watery. Somewhat lower temperatures than normal and adequate ventilation during dark, cloudy weather prevent tipburn during the winter. Where outside temperatures are too high during the fall and spring, care in fertilizing, watering, and ventilating to obtain as solid and firm a growth as possible helps to hold the disease in check.

#### ROOT KNOT

Root knot <sup>11</sup> has never been considered particularly destructive to greenhouse lettuce, but it must be controlled if the best results are to be secured. During the winter season lettuce houses are usually run at such a low temperature that the disease remains dormant and does no damage, but during the warmer weather of fall and spring root knot may cause serious injury. It is very injurious to both cucumbers and tomatoes, and when one or both of these occupy a place in the greenhouse rotation it is especially desirable that the disease be controlled.

Steam sterilization of the soil is an effective control measure if carried out carefully and thoroughly. The microscopic eelworm causing this trouble works down to a depth of a foot or more and penetrates under walks and side walls. Satisfactory results cannot be expected unless the soil is heated at a temperature of at least 212° F. to a depth of at least a foot.

#### INSECTS INJURIOUS TO GREENHOUSE LETTUCE <sup>12</sup>

Lettuce grown in the greenhouse is subject to injury by several insect pests. The most troublesome are plant lice and the white fly, which frequently cause serious damage unless they are checked. The cabbage looper and cutworms occasionally gain entrance to greenhouses and do considerable injury.

##### PLANT LICE AND THE WHITE FLY

##### HYDROCYANIC ACID GAS FUMIGATION

An effective and cheap method of ridding vegetable houses of white fly and plant lice is fumigation with hydrocyanic acid gas. This gas is very poisonous and there is grave danger to the operator and also to the plants being fumigated if extreme care is not exercised in handling the material, but in experienced hands it is a safe, practical, and economical fumigant. A dosage of from one-eighth to one-fourth of an ounce of calcium cyanide per 1,000 cubic feet of air space should be used in an overnight exposure. The variation in the dosage will depend on the tightness of the house. As this dosage does not kill immature forms of the white fly, repeated treatments will be necessary to kill the adult flies after they emerge from the immature pupal stage. More detailed information on the proper method of fumigating with this material may be obtained by consulting your State entomologist or the Bureau of Entomology and Plant Quarantine, Washington, D. C.

<sup>11</sup> Caused by the eelworm *Heterodera marioni* (Cornu) Goodey (*H. radiclecola* (Greef) Müller). See Farmers' Bulletin 1345, Root-Knot: Its Cause and Control.

<sup>12</sup> Prepared by W. H. White, principal entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine.

## NICOTINE FUMIGATION

Nicotine fumigation is used extensively and with effective results for the control of plant lice infesting greenhouse crops. This method, while convenient, is usually more expensive than hydrocyanic acid gas fumigation. The nicotine is made available either by burning tobacco stems, specially prepared paper or powder treated with nicotine, or finely ground tobacco dust, or by vaporizing liquids containing nicotine on special burners or hot steam pipes.

When stems are used they are burned in ashcans or similar containers placed at intervals of 40 to 50 feet throughout the houses, and usually suspended by wires from the frame of the houses so that the heat will not injure the crop. A bushel of stems is sufficient for each 200 to 300 square feet of greenhouse space. The stems should be so moistened that they will burn slowly and produce a dense smoke that will fill all parts of the house. Fumigation is always conducted at night or on cloudy days, care being taken that the plants are dry; otherwise injury may result.

Nicotine papers or powders, tobacco dusts, and tobacco or nicotine liquids prepared for fumigating purposes contain variable proportions of nicotine, and it is advisable to follow directions for their use as given by the manufacturers. The grower is advised to observe carefully the results obtained and if the fumigation is not effective to increase the quantity of material.

## THE CABBAGE LOOPER

The cabbage looper, one of the worms commonly found on cabbage, often gains entrance to greenhouses by being inadvertently carried there; or the moth may enter the house in late fall and deposit eggs upon lettuce or other available food plants.

When attacked by worms the lettuce may be dusted with derris or pyrethrum dusts.

A derris dust containing 1 percent of rotenone is effective and may be prepared by mixing:

Derris powder (4-percent rotenone)-----	pounds--	10
Tobacco dust-----	do-----	30

Obviously, derris or cube powder containing either more or less than 4 percent of rotenone should be mixed with correspondingly more or less of the inert material in order to give a 1-percent mixture.

Pure, fresh pyrethrum powder may be mixed with an equal volume of tobacco dust before being applied. Applications of this material should be made in the afternoon or evening.

If the insects are successfully controlled during the first outbreak there will be little danger of their recurrence.

## CUTWORMS

Cutworms occasionally cause considerable damage to young lettuce. They usually gain access to the greenhouse by being transported in the soil, or the moth may enter the house late in the season and deposit the

eggs from which the worms develop. Cutworms may be controlled by the use of poisoned bait prepared as follows:

White arsenic or paris green-----	pound--	1/4
Sirup or molasses -----	pint--	1
Dry bran-----	peck--	1 (or 5 pounds)
Water-----	quarts--	3 or 4

(1) Thoroughly mix the poison with the bran. This is important. Each particle of bran must carry a little poison to get a good kill. When making small quantities, the bait can be mixed in a bucket with a paddle; the bran should be stirred while the poison is added slowly. A still more effective way is to mix the poison and bran with the hands, but as soluble arsenic is absorbed to a slight extent through the skin, there may be some objection to this method. If the hands have any cuts, scratches, or other wounds, do not put them into the bait.

(2) Mix the sirup with the water.

(3) Add the water and sirup solution to the mixture of bran and poison, stirring slowly all the time. Large quantities of water added at one time will wash the poison from the bran, resulting in an uneven mixture.

Add only enough liquid to make a crumbly mass. It is a good plan to set aside a little of the mixture of dry bran and arsenic, so that if too much water has been used this dry reserve can be added to bring the mixture up to the proper consistency. Large quantities can be made up in galvanized iron or wooden washtubs and small quantities in buckets or similar containers.

To safeguard against cutworm injury, the poisoned bran should be scattered lightly and evenly over the bed late in the evening before the plants are set in the bed. After the plants are set, the poisoned bait should be scattered lightly between the rows to prevent any of it from coming in contact with the lettuce plants, as they may become contaminated with the arsenic or plant injury may result. The presence of arsenic on any part of the plant at the time of harvest may lead to condemnation of the market product because of excessive amounts of the poison. Sterilizing the soil will kill cutworms.